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THE STATUS AND DISTRIBUTION OF ANTS IN THE CRATER DISTRICT OF HALEAKALA NATIONAL PARK

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ABSTRACT

The Crater District of Haleakalā was surveyed for Argentine Ants. Ants were located by turning rocks to locate colonies and by using baits to attract workers. Three species of ants were found. Argentine ants (*Iridomyrmex humilis*) were found only within 1 km of Park headquarters and the nearby research facility. *Hypoponera opaciceps* was found in small numbers throughout the Crater District. *Cardiocondyla emeryi* was present at the head of Kaupō Gap.

Techniques for monitoring and controlling Argentine ants are discussed.

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INTRODUCTION

Three species of ants have become established in the Crater District of Haleakala National Park: *Iridomyrmex humilis* (Mayr) (the Argentine ant), *Hypoponera opaciceps* (Mayr), and *Cardiocondyla emeryi* (Forel). The Argentine ant and *H. opaciceps* were known previously from the Park (Beardsley 1980). The presence of *C. emeryi*, however, is first reported in this paper.

The primary purpose of this study was to determine the range of the Argentine ant within the Crater District of the Park and to assess the potential impact of this species on the endemic, flightless insects inhabiting the crater (e.g., flightless carabid beetles, lacewings, moths, and flies; see Beardsley 1980). During this survey, information was also gathered on the distributions of *H. opaciceps* and *C. emeryi*. The possible threat posed by these ant species to the endemic insects was also evaluated.

The Argentine ant is native to Argentina. With the inadvertent assistance of humans, Argentine ants have spread throughout the northern and southern temperate zones with populations now established in Africa, Australia, Europe, South America, North America, and Hawai'i. The Argentine ant first appeared in the United States in New Orleans during the late 1800's and quickly spread to cover much of the Southeast. It was introduced into California in approximately 1905 (Mallis 1941). The species now occupies many of the milder climatic regions of the State and is considered to be a major pest.

During the 1930's, the Argentine ant was frequently intercepted at quarantine stations on O'ahu in goods shipped from California. Apparently, however, the ant did not become established in Hawai'i until 1940 when active colonies were reported within the boundaries of Fort Shafter, Honolulu (Zimmerman 1941). By 1950, Argentine ants had spread from the Fort to Pearl Harbor, Nu'uanu, Moanalua Gardens, 'Ewa, and the SE ridge of the Wai'anae Range. They were first reported on the windward side of the Island in 1955 at Kaneohe.

By 1950, the Argentine ant had also begun to invade other islands. In November of that year, it was reported at Makawao, Maui, and Kamuela, Hawai'i. Undoubtedly, ants were carried to the other islands by human commerce, most probably via movements of army equipment and supplies. By the early 1960's the Argentine ant had been reported on all of the six main islands except Moloka'i. (See review of pertinent literature by Wilson and Taylor 1967).

Argentine ants are voracious feeders and consume a wide range of foods including honeydew (excretions from certain insects feeding on plant sap), carrion, and other insects. They can be very effective predators on small insects, particularly those with low mobility. In addition, by monopolizing a high proportion of suitable cover objects (rocks, logs, etc.), the ants may prevent other insects from using these items for refuge and thus have a significant, negative impact on invertebrate populations. On the Solomon Islands, another species of *Iridomyrmex* (*I. cordatus* Fr. Smith) has been shown to eliminate all potential prey (i.e., other insects and invertebrates) from the immediate vicinity of their colony (Greenslade 1972). The Argentine ant may have a similar effect, though this has not been adequately documented.

The Argentine ant reaches extremely high densities in many areas. For example, Heer (1892, in Wheeler 1910) reports that Argentine ants on the island of Madeira (off the NW coast of Africa) could be found under eight out of every 10 stones. In California, Tremper (1975) found that populations of Argentine ants were denser than the combined populations of all native ant species in adjacent areas.

The development of such large populations is facilitated by the somewhat unusual life history of the Argentine ant. Most species of ants establish distinct colonies, each with one queen and many workers. These colonies are generally hostile to one another, defending food sources and nest sites. Colonies produce winged reproductives (males and females) which leave the nest in a nuptual flight where mating occurs. The young queens are fertilized, fall to the ground, lose their wings, and establish new colonies. The new queen lays eggs which become the first workers in the young colony.

Argentine ants do not engage in nuptual flights. Virgin queens are fertilized inside the nest and colonies may have several hundred queens. This large number of queens allows for rapid production of many workers. When the colony reproduces, groups of workers with one or more queens simply move out of the parent colony and found a new nest nearby. In this way, the initial colony spreads slowly outwards forming a huge "supercolony." There is no hostility between nests within the supercolony and ants from all parts of the colony follow the same odor trails and cooperate in food-gathering. As a consequence, the Argentine ant population of a given area can reach extremely high densities.

The high population density of Argentine ants, as well as their very aggressive nature towards other invertebrates, makes them exceedingly effective competitors. Where Argentine ants are abundant, they monopolize food sources, foraging areas, and nest sites, which makes it difficult for other ant species to survive. Argentine ants frequently eliminate all other ants from the area. This replacement has been well-documented in Hawai'i (Fluker & Beardsley 1970), Bermuda (Haskins & Haskins 1965; Crowell 1968; Lieberburg et al. 1975), and California (Tremper 1975).

The inadvertent introduction of the Argentine ant into Haleakala National Park has very serious implications for the invertebrate fauna of the Park. The endemic, flightless insects found in the crater region of Haleakalā are particularly vulnerable to predation and displacement by Argentine ants. If Argentine ants become well-established in the crater, they could conceivably cause the extinction of these unique forms (Beardsley 1980: 7-9). Dense populations of the Argentine ant now occur in the vicinity of Park Headquarters. This study determines the extent of the ant's range within the Park and evaluates the threat posed to endemic insects living in the crater itself.

The habits of the other two ant species found in the Park, *H. opaciceps* and *C. emeryi*, are less well known than those of the Argentine ant. *Hypoponera opaciceps* is a very widespread species occurring on many islands of the South Pacific including the six main Hawaiian Islands, Society Islands, Australs, and the Marquesas. The species probably originated in the New World where it is common from the southern U. S. to Uruguay. Populations of *H. opaciceps* are also found in the Old World but these are quite localized.

Cardiocondyla emeryi is native to India (Wilson & Taylor 1967) but has been widely distributed by human commerce and is now found on many islands in the Pacific region. In Hawai'i, *C. emeryi* has been reported from the six largest islands where it is abundant at lower elevations with relatively little rainfall (Huddleston & Fluker 1968). The species was not known previously from Haleakala National Park.

METHODS

Transect Methods

Several techniques can be used to census ants. Two of the most efficient are (1) turning cover items to locate colonies and (2) using baits to attract workers. We employed both of these techniques in our study.

Many species of ants (including the Argentine ant) establish colonies under some type of surface cover and hence can be censused by turning appropriate cover items. Since the terrain at Haleakala is generally rocky, we were able to locate suitable cover rocks in all areas censused. A cover-item transect consisted of 50 rocks which appeared to provide suitable cover. In general, such rocks were at least 10 cm across and resting firmly on the soil. When ants were located under a rock, we recorded whether only a few workers or a colony were present. If there was a colony, we also noted the presence of any reproductives or brood. Such information can be useful in assessing the general vigor of the ant population.

The second census method involved a combination of bait transects and cover rocks. The baiting was designed primarily to locate workers and to estimate their density. Honey and liver patê were used as baits. We selected these foods because preliminary experiments on Argentine ants conducted in California indicated that honey and liver paté attracted ants more quickly and consistently than any of the other baits tested (i.e., various jellies, peanut butter, cheese, spam spread, yeast, and baby food).

Each bait used in our Haleakalā transects consisted of a small portion of honey and liver paté placed on a white file card cut to approximately 6.5 x 7.5 cm. The use of file cards does not interfere with ant activity (Fellers 1977) and greatly facilitates the relocation of baits and the counting of ants.

Bait transects consisted of 50 baits set out in two parallel rows of 25 each. Baits were placed approximately 2 m apart, thus resulting in two 50-m rows. These rows were separated by approximately 25 m. When a road (or trail) was present, transects were oriented 90° to the road and began at the edge of the road so as to detect any changes in ant density which might be associated with roads or trails.

Baits were left in place for 40 minutes in order to give ants ample opportunity to locate them. After this time, we collected baits and recorded the number of ants present at each bait. Exact numbers of ants were counted for baits with fewer than 10 individuals, and numbers were estimated to the nearest 10 for baits with more than 10 ants present.

At each baiting locality, we also turned 25 suitable cover objects. This additional census technique provided a means of direct comparison between bait and cover item transects.

To summarize our methods, we used two types of transects: (1) cover-item transects in which 50 suitable rocks were turned at each locality and (2) bait transects in which we used 50 baits and turned 25 suitable rocks.

At each locality sampled (by either method), we recorded air temperature in the shade, ground temperature in both the sun and the shade, general vegetation type, major plant species present, general soil description, qualitative description of soil moisture, slope, and relative abundance of suitable cover items.

Transect Placement

During the study, 56 transects were conducted (32 cover-item transects and 24 bait transects) for a total coverage of 2200 rocks and 1200 baits (Fig. 1).

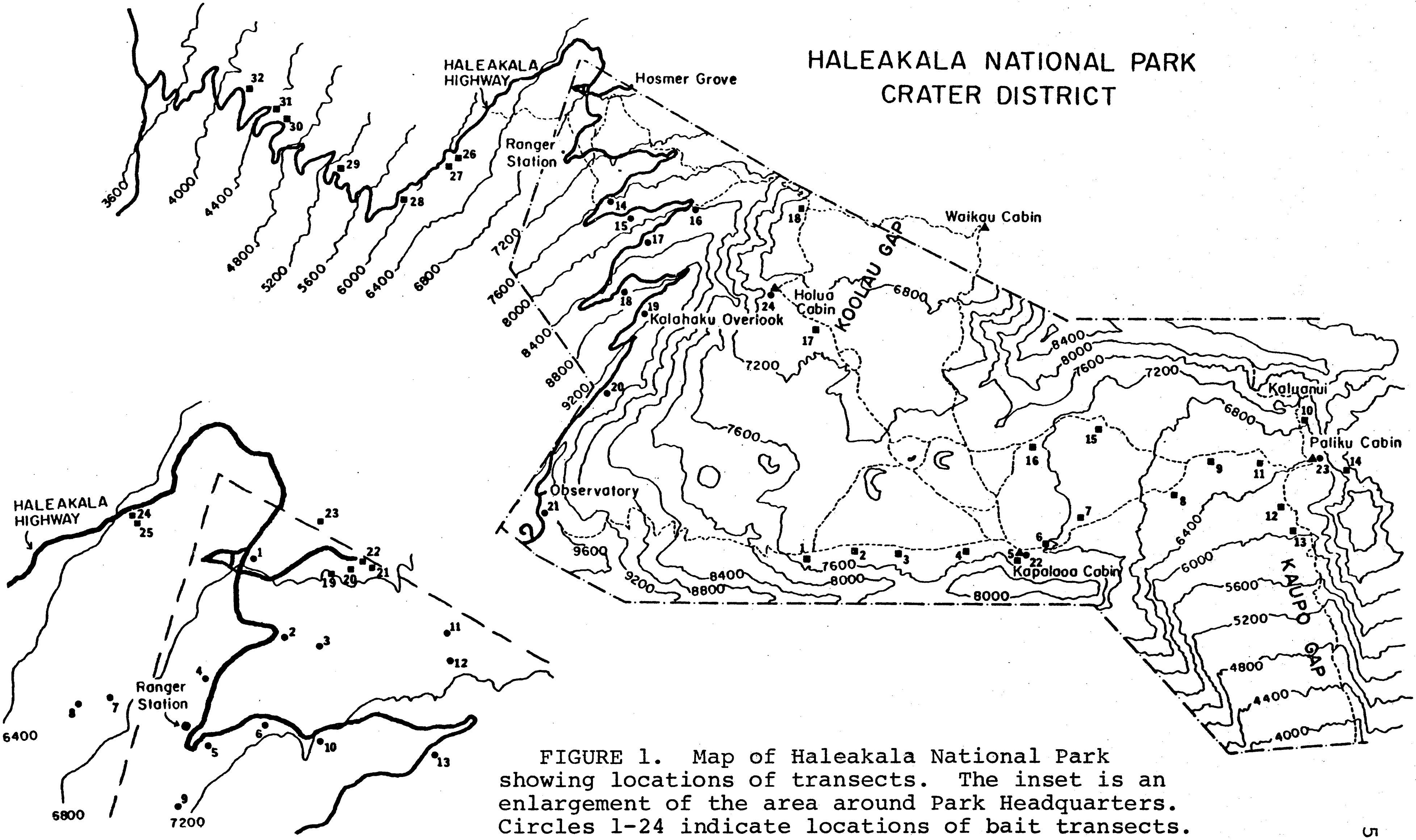

FIGURE 1. Map of Haleakala National Park showing locations of transects. The inset is an enlargement of the area around Park Headquarters. Circles 1-24 indicate locations of bait transects. Squares 1-32 indicate localities for cover-item transects (referred to as localities R-1 through R-32 in the text).

Twenty-one of the bait transects were conducted along or near the Park road. Along the road, transects were conducted at 200-foot intervals in elevation from 6800 feet up to 8200 feet. Above 8200 feet, transects were spaced at 400-foot intervals up to 9800 feet. Three additional roadside localities (2, 5, & 6) were added later in areas of particular interest. Bait transects were also conducted at the three cabins within the crater: Kapalaoa, Palikū, and Hōlua.

Cover-item transects were carried out at 18 sites within the crater. We spaced these transects fairly evenly through habitat with at least some vegetation and appropriate cover. Cinder-covered areas with no vegetation were not sampled as this habitat was not suitable for Argentine ants. Fourteen cover-item transects were also conducted near Hosmer Grove and on the lower slope of Haleakalā below the Park boundary.

All transects were conducted between June 17 and 28, 1980.

RESULTS

Three species of ants were found in the Park during this study: *Iridomyrmex humilis*, *Hypoponera opaciceps*, and *Cardiocondyla emeryi*.

Iridomyrmex humilis (the Argentine ant)--We found the Argentine ant to have a very restricted range in the Crater District of the Park. Only eight of the 44 transects conducted within Park boundaries revealed the presence of Argentine ants (Tables 1 & 2). All eight of these sites were on the lower northwestern slope of Haleakalā, within approximately 1 km of either Park Headquarters or the research facility. This area is characterized by a fairly dense cover of shrubs, primarily pūkiawe, 'ōhelo, and māmane. The ground has a moderately steep slope with fine soil and scattered rocks.

Argentine ants were also found in several places outside the Park, below Park Headquarters, and along Route 378. No Argentine ants were located on the northwestern slope above 7200 feet or anywhere within the crater itself. Figure 2 shows the transect sites which were inhabited by the Argentine ant and gives an extrapolated range of this species in the vicinity of the Park.

In those areas which were occupied, Argentine ant populations were very dense. Five of the seven bait transects within their range had over 2000 ants and attracted ants to every bait (Table 1). One of these transects (locality 7) had 6085 ants at the 50 baits, the largest number at any of the localities tested. Both bait and cover-item transects demonstrated that a high proportion of the suitable rocks harbored ants. As many as 84% of the rocks were occupied in some transects (Tables 1 & 2). Rocks occupied by Argentine ants were rarely used by any other invertebrates. This observation suggests that the ants are

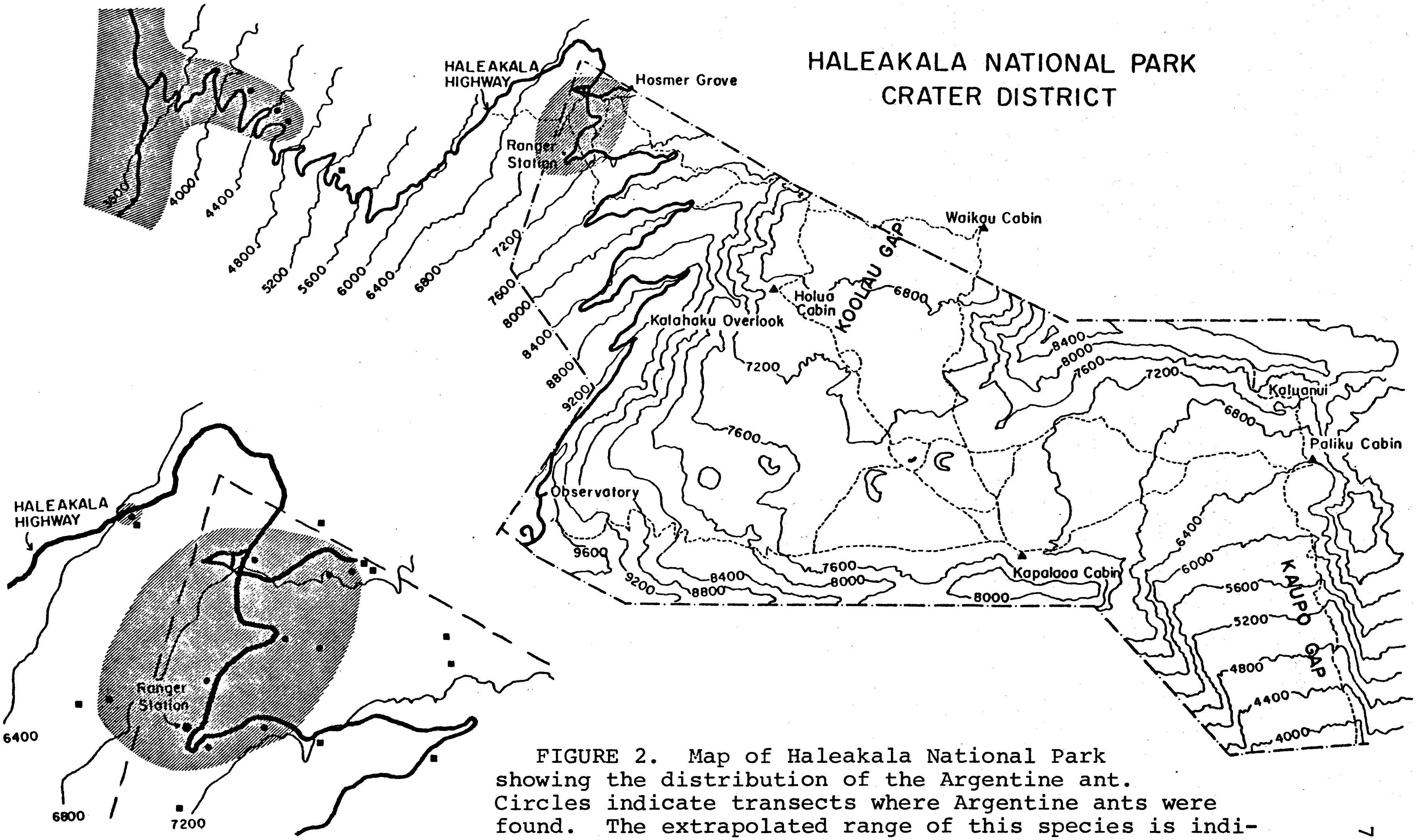

FIGURE 2. Map of Haleakala National Park showing the distribution of the Argentine ant. Circles indicate transects where Argentine ants were found. The extrapolated range of this species is indicated by the shaded areas. Localities just outside the range which did not have Argentine ants are shown by squares.

superior competitors and eliminate other invertebrates from these important refuges.

The Argentine ant population in the Park was reproductively active since brood and/or reproductive individuals were present in many colonies (Tables 1 & 2). There was a general (though not statistically significant) trend for reproduction to be stronger in the center portion of the range and somewhat decreased towards the periphery (Table 3).

At the edge of the range, the numbers of ants attracted to baits dropped abruptly over a very short distance (Table 4). In bait transects 7 and 8, for example, the number of ants fell from 6085 to zero over a distance of approximately 150 m. Similarly, in the 450 m between transects 5 and 6, ant numbers dropped from 2430 ants (50 of 50 baits occupied) to 17 ants (eight of 50 baits occupied).

Not surprisingly, the proportion of suitable rocks harboring ants was correlated with the number of ants present at baits, with fewer rocks occupied in areas with fewer ants (Table 5). In no case did we find ants at baits without also locating them under rocks. This result substantiated the validity of surveying for the presence of Argentine ants with only cover-item transects, particularly since we examined twice as many rocks in the cover-item transects as in the bait transects.

Hypoponera opaciceps.--This small, secretive species was found throughout the Crater District (Fig. 3; Table 6). It occupied areas with dense brushy vegetation, trees, sparse shrubs, grassland, or even cinder with only scattered bracken ferns. Wherever this species occurred, it was found in very low numbers (usually 1-2 individuals) under only a small proportion of the rocks turned (< 15%, see Table 6). On only two occasions did we find *H. opaciceps* colonies with several individuals and a brood.

Hypoponera opaciceps never came to baits and could best be located by turning rocks and watching for movement for at least 30 seconds. Since the first reaction of this tiny ant was to freeze, it could be easily overlooked even by careful observers. In fact, on the first day of our survey, we did not expect to find *H. opaciceps* and were looking primarily for Argentine ants. Hence we did not search as carefully at localities 1, 14, and 16 to 21, although we feel that *H. opaciceps* is likely to have been present at any but the first of these localities.

Despite its broad habitat tolerance, *H. opaciceps* was rarely found at the same locality as the Argentine ant (Table 6). At sites where both species occurred (locality R-32, also between localities 7 & 8 and between localities 5 & 9 where no complete transects were conducted), the Argentine ant was at the very edge of its range. At locality R-32, Argentine ants were under several rocks on one side of the road while *H. opaciceps* was on the other side of the road where there were no Argentine ants. Although this difference in distribution appeared to be real,

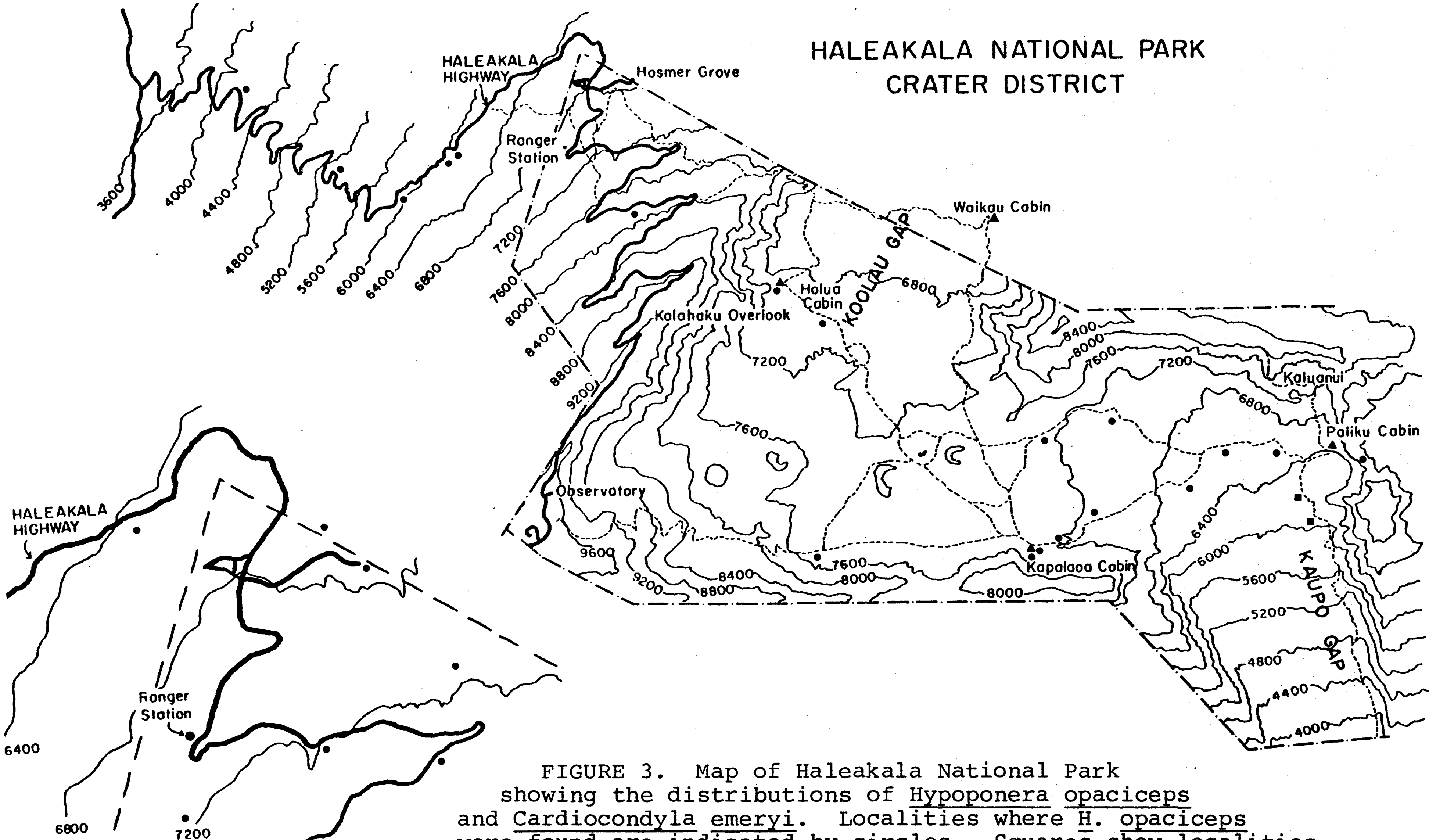

FIGURE 3. Map of Haleakala National Park showing the distributions of *Hypoponera opaciceps* and *Cardiocondyla emeryi*. Localities where *H. opaciceps* were found are indicated by circles. Squares show localities for *C. emeryi*.

it is possible that we overlooked the relatively inconspicuous *H. opaciceps* in areas where Argentine ants were extremely numerous and active.

Cardiocondyla emeryi.--*C. emeryi* is a small ant (1.6 mm) about the size of *H. opaciceps* but much more active. We found *C. emeryi* at two localities (R-12, R-13), both situated in the crater at the head of Kaupō Gap (Fig. 3). The species was relatively uncommon at these localities, occupying only 8% and 2%, respectively, of the rocks turned. These colonies, however, were very active with many workers, reproductives, and brood.

DISCUSSION

The distribution of Argentine ants in Haleakala National Park follows a very distinct pattern. Ants are abundant within about 1 km of Park buildings but their numbers decrease abruptly to zero at the edge of their range. This pattern is repeated outside the Park boundary along Route 378 where ants are present only within about 1 km of houses. One isolated population exists along Route 378 at 6430 feet, 1.1 miles northwest of the Park boundary. This population occupies a disturbed site along a short section of abandoned dirt road. The range of this population is very restricted, however, as no ants were present 125 m upslope from Route 378.

Argentine ants probably became established at Haleakalā in the vicinity of the Park buildings. Discussions with Park employees Carole Beadle and Adele Fevella indicate that ants have been present for at least 7 to 10 years. While it is possible that the current distribution represents the distance the Argentine ant has spread in that time, this seems unlikely. Ants regularly travel 10 to 15 m while foraging and typically move their colony site several times within the course of one season (Wilson 1971).

The best explanation of the current distribution is that park buildings moderate the occasionally harsh climate at Haleakalā. If Haleakalā is only marginal habitat, the Argentine ant may do well during relatively mild years but may be unable to survive harsh years except with the moderating effect of buildings. If this were the case, ants would die out everywhere during harsh years except in the vicinity of the buildings. During intervening mild periods, ants would spread gradually until they were knocked back again by the next harsh season. In this way, the ants' range would fluctuate as influenced by the weather of the previous year.

Huddleston and Fluker (1968) report that the Argentine ant in Hawai'i is commonly found in habitats from sea level to 6000 feet. Thus, Argentine ants at Haleakalā are at the very edge of their altitudinal range and are likely to encounter only marginally-acceptable conditions. A long-term monitoring program would be necessary to prove or disprove the climatic hypothesis for the range of the ant. (See Management Recommendations).

The specific climatic factor which regulates the Argentine ant population is most likely to be either cold temperatures or prolonged drought. Both of these factors are important in determining the range of the Argentine ant in other parts of the world. Mallis (1941) states that the Argentine ant is limited in its distribution by its moisture requirements and "by an inability to thrive where it cannot be protected from long periods of cold weather such as is encountered at higher altitudes." Argentine ants from California were shown to be intolerant of dry conditions in physiological experiments (Tremper 1975). This physiological limitation correlated well with their range in California where they occurred only in moist areas. The climatic factor responsible for the range of the Argentine ant at Haleakalā could be determined by a long-term monitoring program.

We considered several other possible explanations for the range of the Argentine ant at Haleakalā. Once the data were collected, none of these hypotheses seemed very likely. A brief description of these hypotheses follows.

1. Unusually heavy rains in 1980. For several reasons it seems unlikely that the distribution of Argentine ants was significantly influencd by the unusually heavy rains which occurred from January to early April 1980. If Argentine ants had ever been established at any of the cabins in the crater, their presence would have been readily noted by both campers and maintenance personnel (who collected the garbage). While the distribution of ants in the vicinity of Park headquarters may have been influenced by the weather, the data suggest otherwise. The ant colonies had numerous reproductives and eggs indicative of well established, healthy colonies, not ones recovering from a climatic catastrophy. Also, while colonies were restricted to within 1 km of Park buildings, the distribution and density of colonies is greater than what could have been established in the two months between the end of heavy rains and our surveys.

2. Elevation. Ants could have occurred everywhere below a particular elevation. This possibility is ruled out by the disappearance of ants below the Park buildings and by the lack of correlation between the ants' upper boundary and any particular elevation.

3. Habitat. Ant distribution might have been determined by a specific habitat factor such as soil type or vegetation. We could find no habitat change which corresponded with the ants' range. In fact, there appeared to be more variation between different areas occupied by ants (e.g., T-2 & R-32) than between adjacent areas with and without ants (e.g., R-7 & R-8).

4. Human disturbance of habitat. Ants could exist only in areas where the habitat was disturbed by human activity. While ants at Haleakalā were fairly near buildings, the habitat did not appear to be disturbed significantly except in the immediate vicinity of the buildings.

One major aspect of this study was to survey the interior of Haleakalā crater for Argentine ants which might be threatening the endemic insect fauna. Since we found no Argentine ants in the crater, there is no immediate danger. Our observations of the habitat, however, indicate that at least some areas are suitable for ants with respect to vegetation, soil conditions, and cover objects.

Ants could easily be transported into the Crater by Park visitors, rangers, pack animals, or supply helicopters. Apparently no introduction has yet occurred or past introductions have not become established. Given the ease with which ants are transported, it seems likely that ants have been introduced in the past but have not been able to establish new colonies. Two explanations can be offered to account for this lack of success.

1. The same climatic factors which regulate ant populations near Park Headquarters are also operating in the crater. The crater floor is at a high enough elevation to occasionally experience winter temperatures below freezing. It is subject also to periods with no rain. Thus, harsh conditions could make the crater unsuitable for Argentine ants. The cabins may not provide sufficient moderation of the weather, perhaps because they are not occupied continuously or because they are not heated adequately in winter.

2. Past introductions may have included workers but no queen or brood. New colonies cannot be established by workers without a queen, or at least a brood from which a new queen can be raised. This explanation seems somewhat unlikely, however, as the small queens of this species sometimes forage with workers and are thus relatively easily transported. In addition, workers move the brood into temporary nest sites quite frequently. This behavior would facilitate introduction of brood into supplies which then could be carried into the crater.

Given the apparent suitability of the crater habitat for Argentine ants and the ecological sensitivity of the crater area, we would recommend that National Park Service (NPS) personnel monitor the cabin areas closely for the presence of ants. (See Management Recommendations).

Two other ant species were found in the Crater District during this study, *Hypoponera opaciceps* and *Cardiocondyla emeryi*. *Hypoponera opaciceps* was known previously from two localities within Haleakala National Park (Hosmer Grove and Kuiki; Beardsley 1980) and from one locality along Route 378. Huddleston and Fluker (1968) report that it is most frequent in the wet mountain areas of Hawai'i but is also found occasionally in areas with less than 40 inches of rain. We found _H. opaciceps_ to be very widespread in the Crater District, from wet areas such as the notch above Palikū to relatively dry areas such as the cinder zone at the base of Sliding Sands Trail. _Hypoponera opaciceps_ also occupies a wide variety of habitats from areas of bracken fern to grassland to dense shrub.

Hypoponera opaciceps belongs to the subfamily Ponerinae. Members of this subfamily are known to be predacious (Wheeler 1910). Our observations, however, indicate that _H. opaciceps_ is probably not a serious threat to the native invertebrate fauna. Colonies of this species were not abundant at any locality and are known to be quite small (fewer than 50 individuals; Huddleston & Fluker 1968). The ant itself is small and slow-moving, spending most of its time under cover and rarely appearing on the surface. We noted that rocks occupied by _H. opaciceps_ also supported a variety of other invertebrates (although these may also have been exotics). By contrast, the Argentine ant is extremely numerous, has huge colonies, is very active, and is rarely found with any other invertebrates. The Argentine ant most certainly has a far larger impact on the native fauna than does _H. opaciceps_ (Snelling, pers. comm.).

Our survey suggests that _H. opaciceps_ may be displaced by the Argentine ant. We found very little overlap in the ranges of these two species. The Argentine ant is well-known for its aggressiveness and has supplanted other ant species in several parts of the world including O'ahu, Bermuda, and California (Haskins & Haskins 1965; Crowell 1968; Fluker & Beardsley 1970; Lieberburg et al. 1975; Tremper 1975). A similar replacement may be occurring at Haleakalā.

The third species found during our survey was _Cardiocondyla emeryi_. We found _C. emeryi_ at two localities (R-12 & R-13) in the crater at the head of Kaupō Gap. The species may be moving up the Gap from populations at lower elevations; however, further work would be needed to establish the distribution of _C. emeryi_ in the Park.

Members of the genus _Cardiocondyla_ are not particularly aggressive towards other ant species, nor are they very efficient foragers (Wilson 1971). Little is known, however, about the impact of _C. emeryi_ on other insects. Although we found colonies of _C. emeryi_ to be sparsely distributed, they were quite active and contained both reproductives and brood. They occupied more of the space beneath rocks than _H. opaciceps_ but less than the Argentine ants. At present _C. emeryi_ seems unlikely to have any significant effect on the native insect fauna (Snelling, pers. comm.). If the species were to become more abundant, it could compete with the native invertebrates for food and space. We recommend that _C. emeryi_ populations be checked periodically by NPS personnel. (See Management Recommendations).

CHEMICAL CONTROL OF ANTS

Attempts to control ant populations on a large scale by means of pesticides have been fraught with difficulty and have met with limited long-term success. The best means of controlling ants with pesticides is to use poison baits. Compared with broadcast sprays, the use of baits reduces the negative effects on non-target organisms because, for the most part, only those animals which eat the baits, or which eat the dead ants, will be affected. Any use of poison, however, can have serious side effects. (See literature review on poison control of ants by Su 1979).

In order to be effective, a poison must (a) not make the bait unattractive to ants; (b) be readily transferred from one ant to another; (c) exhibit delayed toxicity (so poison becomes active after the ant has carried it back to the colony); and (d) be effective over at least a ten-fold and preferably a hundred-fold range of doses (Su 1979).

One effective poison used in bait control of fire ants in the southeastern U. S. was mirex. This poison soon proved to have serious environmental effects and also to be a mild carcinogen. As a result, the Environmental Protection Agency (EPA) prohibited its use after 1978. (See Ehrlich et al. 1977 for review of mirex).

The ban on mirex has stimulated research on other possible poisons for ant control. Very few poisons appear to have much potential. The most promising one seems to be AC 217,300 (AMDRO) which Su (1979) has used with some success against the big-headed ant (*Pheidole megacephala* Fabr.) in pineapple fields on Moloka'i. Since AC 217,300 is a relatively new insecticide, its environmental effects should be well-studied before it is considered seriously for use in the Park.

We feel that the National Park Service should be very hesitant about employing pesticides at Haleakalā. Several serious drawbacks are inherent in pesticide use.

1. Effects on non-target organisms. Insecticides are not specific in what they kill. Consequently insecticide use may have a serious effect on populations of many animal species including the native insect fauna. Effects on non-target organisms have been well-demonstrated by DDT, for example.

2. Pesticide residues can accumulate in the environment with the potential for serious future damage to non-target organisms.

3. Certain pesticide residues provide a health hazard for humans (e.g., mirex).

4. Target insect species tend to become resistant to pesticides so that their effectiveness decreases and larger doses must be used or new pesticides found.

The Argentine ant is a particularly difficult species to deal with because it can easily reinvade areas from which it has been removed. The large number of queens per colony and the high reproductive rate also make it difficult to eliminate the population. Populations which are only reduced in size have the capacity to expand rapidly because of their high fecundity.

Since the Argentine ant is not currently threatening the endemic insect fauna and since its range within the Park appears to be limited by climatic factors, the potential benefits of pesticide use seem to be outweighed by the disadvantages. If the ant were to gain a foothold inside the crater, however, a very limited program of poison baiting should be considered. One of the newer insecticides, such as AC 217,300 or bendiocarb, might then be used to eliminate the infestation before the population becomes firmly established (Beardsley, pers. comm.). At that time, the National Park Service should obtain the advice of both a qualified toxicologist and an ant ecologist in order to devise the most effective and least damaging technique.

MANAGEMENT RECOMMENDATIONS

1. Monitor Argentine ant populations inside the crater.

It is extremely important to detect the appearance of Argentine ants in the crater as soon as they become established. Since the cabins are the most likely sites of introduction, efforts should be focused there. This monitoring program could be conducted very simply during routine maintenance by checking garbage cans at the cabins for ants. One backcountry ranger should be put in charge of checking for ants. After each trip into the crater, this person would be responsible for entering observations in a data book. All that would be necessary is a simple + or - indicating presence or absence of ants at each of the four cabins (Kapalaoa, Palikū, Ranger cabin, and Hōlua). It is very important that this monitoring program be established and rigorously followed. If ants are found at the cabins, the Park superintendent, scientist, and resource manager should be notified immediately. At that time, a more extensive search can be made and appropriate action taken. (See comments on Chemical Control of Ants).

2. Monitor Argentine ant populations near Park Headquarters.

This procedure would enable NPS scientists to determine if climatic factors are restricting the ant's range within the Park, and if so, which specific factors are responsible. Twice per year (late spring and early fall), Park personnel should determine the exact distribution of the Argentine ant along the Park road above Park Headquarters. To do this survey, a ranger should walk parallel to, but a little ways off, the road. At 100-yard intervals he should turn, and carefully replace, suitable rocks. Suitable rocks are generally no smaller than one's hand and firmly in contact with the ground. If a rock is so deeply embedded in the soil that it is difficult to turn, it is not as likely to be suitable for ants. As soon as he finds five rocks with ant colonies, the ranger should proceed another 100 yards. When 25 suitable rocks can be turned without finding any ants, the ranger can assume he is outside the range of the ant. By going back towards the previous 100-yard site (where ants were found) and turning rocks in between, the exact edge of the range can be located. This boundary must then be plotted carefully on a map. It is very important that the map be marked accurately or errors will result in the interpretation of the data. If possible, the same person should conduct the survey on each occasion to insure that the procedure is always carried out the same way.

To determine which climatic factors influence the Argentine ant, accurate information must be obtained on weather patterns in the Park. Specifically, maximum and minimum temperatures, rainfall, and humidity should be recorded, preferably on a daily basis, at Park Headquarters. These climatic factors can then be correlated with fluctuations in the distribution of the Argentine ant.

3. Monitor populations of *Cardiocondyla emeryi* inside the crater.

The abundance of this species needs to be monitored to see if it is increasing. If this ant were to extend its range within the crater, it might pose a threat to the native invertebrates.

Three localities should be selected for monitoring on a yearly basis (once each summer). We suggest our localities R-12 and R-13 and one additional locality 0.25 mile farther into the crater (i.e., north) from R-12. At each locality, 50 suitable rocks would be turned, carefully replaced, and the number of rocks with *C. emeryi* recorded. These data should be examined for increases in ant density and changes in distribution. If possible the same person should conduct the survey each year to insure that results will be comparable from year to year.

4. Additional invertebrate surveys at Haleakala National Park.

Beardsley (1980) has recently surveyed the Crater District for insects and has certainly recorded most of the species which can be trapped using standard entomological techniques. The fact that our brief survey located one species of ant entirely new to the Park (*C. emeryi*) and greatly extended the range of another (*H. opaciceps*), indicates that it is important to encourage further surveys for invertebrates, especially for those not normally captured by the standard baits and traps.

We recommend that the Park conduct an ant survey of the Kīpahulu Valley at the earliest possible opportunity. Ants are often voracious predators and may pose a serious threat to native insects. The Kīpahulu Valley itself is far better ant habitat than is the Crater District. In order to protect the natural resources of Kīpahulu Valley, the Park manager needs to know which species of ants are there and which, if any, pose a problem.

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TABLE 1. Argentine ants found at bait transects.

Locality	Elev. (ft)	# Ants	% Baits Occupied	% Rocks Occupied	% Occupied Rocks[1] Showing Ant Reproduction
1	6800	2315	100	56	50
2	6900	2980	100	84	19
3	6960	1062	96	16	25
4	7000	2750	100	84	57
5	7080	2430	100	80	50
6	7140	17	16	8	0
7	6700	6085	100	68	24
8	6600	0	0	0	0
9	7160	0	0	0	0
10	7200	0	0	0	0
11	7040	0	0	0	0
12	7160	0	0	0	0
13	7400	0	0	0	0
14	7600	0	0	0	0
15	7800	0	0	0	0
16	8000	0	0	0	0
17	8200	0	0	0	0
18	8600	0	0	0	0
19	9000	0	0	0	0
20	9400	0	0	0	0
21	9800	0	0	0	0
22	7240	0	0	0	0
23	6400	0	0	0	0
24	6900	0	0	0	0

[1] Reproductive ants and/or brood were present.

TABLE 2. Argentine ants found at cover-item transects.

Locality	Elev. (ft)	% Rocks Occupied	% Occupied Rocks[1] Showing Ant Reproduction
R- 1	7440	0	0
R- 2	7340	0	0
R- 3	7340	0	0
R- 4	7320	0	0
R- 5	7320	0	0
R- 6	7200	0	0
R- 7	7140	0	0
R- 8	6660	0	0
R- 9	6620	0	0
R-10	6820	0	0
R-11	6460	0	0
R-12	6280	0	0
R-13	6040	0	0
R-14	7000	0	0
R-15	7040	0	0
R-16	7300	0	0
R-17	7000	0	0
R-18	6620	0	0
R-19	6780	70	40
R-20	6760	2	0
R-21	6760	0	0
R-22	6740	0	0
R-23	6700	0	0
R-24	6430	52	27

TABLE 2.--Continued.

Locality	Elev. (ft)	% Rocks Occupied	% Occupied Rocks[1] Showing Ant Reproduction
R-25	6460	0	0
R-26	6040	0	0
R-27	6000	0	0
R-28	5880	0	0
R-29	5300	0	0
R-30	4600	2	0
R-31	4400	16	13
R-32	4150	24	42

[1] Reproductive ants and/or brood were present.

TABLE 3. Reproductive activity of the Argentine ant at the center vs periphery of its range at Haleakala National Park.

Locality	% Occupied Rocks[1] Showing Ant Reproduction	Rank (from smallest to highest percentage)
Center of Range		
1	50	7.5
2	19	3.0
4	57	9.0
5	50	7.5
Periphery of Range		
3	25	5.0
6	0	1.5
7	24	4.0
R-19	40	6.0
R-20	0	1.5

Wilcoxon Rank Sum Test (Hollander & Wolfe 1973):

$$W = \sum_{j=i}^{n} R_j$$

$$= 18$$

$P > 0.35$, no significant difference between the center and periphery

[1] Reproductive ants and/or brood were present.

TABLE 4. Numbers of Argentine ants at the center vs edge of their range at Haleakala National Park.

Locality at Center of Range (Locality A)	Locality at Edge of Range (Locality B)	# Ants at Locality A (at baits)	# Ants at Locality B (at baits)	Distance Between Localities A & B (m)
5	6	2430	17	450
7	8	6085	0	150
		% Rocks Occupied at Locality A	% Rocks Occupied at Locality B	Distance Between Localities A & B
R-19	R-20	70	2	100
R-24	R-25	52	0	100
R-32	R-31	16	2	500

TABLE 5. Correlation between number of Argentine ants at baits and number of rocks occupied by ants.

Locality	# Ants at Baits	# Rocks[1] Occupied
6	17	2
3	1062	4
1	2315	14
5	2430	20
4	2750	21
2	2980	21
7	6085	17

Correlation coefficient (r) = 0.655

$t = 1.9382$

$t_{0.05,5} = 0.755$

$\therefore$ a significant correlation exists between number of ants at baits and number of rocks occupied

[1] Out of 25 rocks turned.

TABLE 6. Distribution and abundance of Hypoponera opaciceps at Haleakala National Park.

Locality[1]	% of Rocks with H. opaciceps[2]	Presence of Argentine Ants at Locality (+/-)
2	0	+
3	0	+
4	0	+
5	0	+
6	0	+
7	0	+
8	0	-
9	4	-
10	4	-
11	0	-
12	0	-
13	4	-
15	8	-
22	12	-
23	0	-
24	8	-
R- 1	2	-
R- 2	0	-

[1] Some localities were not searched for H. opaciceps and have been omitted from this table (see text).

[2] Locality 1-24, 25 rocks turned;
Locality R1-R32, 50 rocks turned.

TABLE 6.--Continued.

Locality[1]	% of Rocks with H. opaciceps[2]	Presence of Argentine Ants at Locality (+/-)
R- 3	0	-
R- 4	0	-
R- 5	2	-
R- 6	6	-
R- 7	10	-
R- 8	14	-
R- 9	2	-
R-10	0	-
R-11	6	-
R-12	0	-
R-13	0	-
R-14	8	-
R-15	2	-
R-16	4	-
R-17	2	-
R-18	0	-
R-19	0	+
R-20	0	+

[1] Some localities were not searched for H. opaciceps and have been omitted from this table (see text).

[2] Locality 1-24, 25 rocks turned;
Locality R1-R32, 50 rocks turned.

TABLE 6.--Continued.

Locality[1]	% of Rocks with *H. opaciceps*[2]	Presence of Argentine Ants at Locality (+/-)
R-21	0	-
R-22	6	-
R-23	2	-
R-24	0	+
R-25	10	-
R-26	4	-
R-27	4	-
R-28	2	-
R-29	8	-
R-30	0	+
R-31	0	+
R-32	2	+

[1] Some localities were not searched for *H. opaciceps* and have been omitted from this table (see text).

[2] Locality 1-24, 25 rocks turned;
Locality R1-R32, 50 rocks turned.